Projection or depixelating screen

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- european:	G02F1/1335D; G03B21/60; G03B21/62
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Priority number(s):	GB19960013802 19960701

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Abstract of **GB2314943**

A projection screen comprising a sheet 10 of light diffusing material incorporating an array of features characterised by relatively abrupt surface level such as frusto-conical shapes (14) to form a diffractive array. This diffractive array (14) can be used as a depixelating material wherein a pixielated LCD screen is spaced from the element or screen by a polariser and an optional spacer. The features may in the shape of ellipses, triangles, pyramids or rectangles as well as cones.

Fig.2.

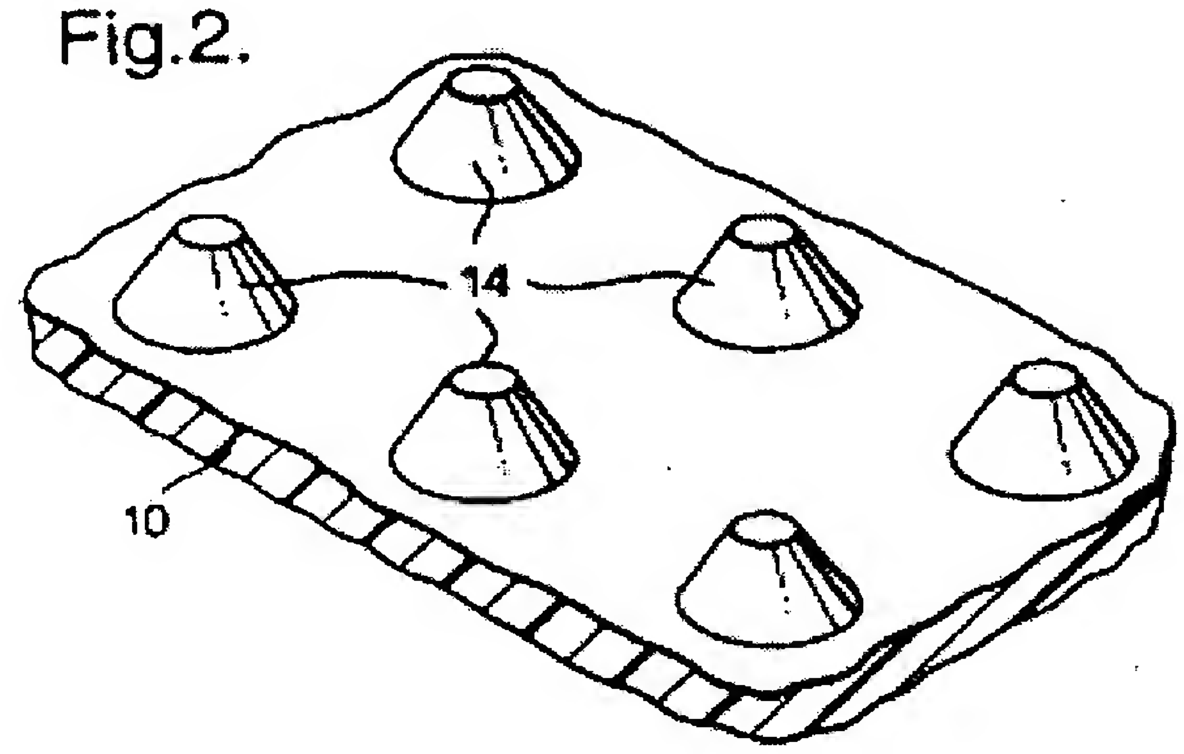
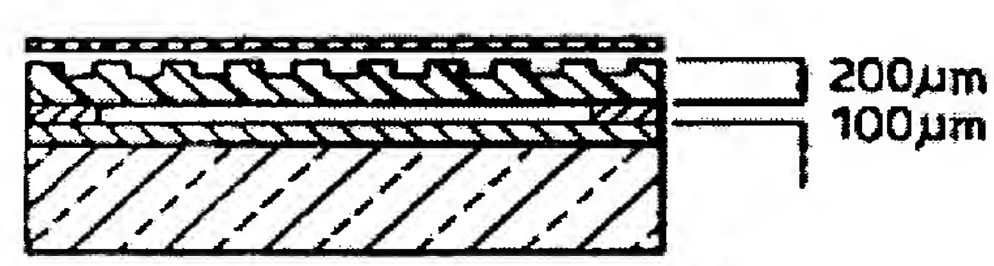


Fig.8.



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G2F FSX F25F

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US 4329019 A US 3966301 A

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UK CL (Edition O) G2F FSX , G2X X42B
INT CL[6] G02B , G02F , G03B

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(74) continued overleaf

(54) **Projection or depixelating screen**

(57) A projection screen comprising a sheet 10 of light diffusing material incorporating an array of features characterised by relatively abrupt surface level such as frusto-conical shapes (14) to form a diffractive array. This diffractive array (14) can be used as a depixelating material wherein a pixielated LCD screen is spaced from the element or screen by a polariser and an optional spacer. The features may in the shape of ellipses, triangles, pyramids or rectangles as well as cones.

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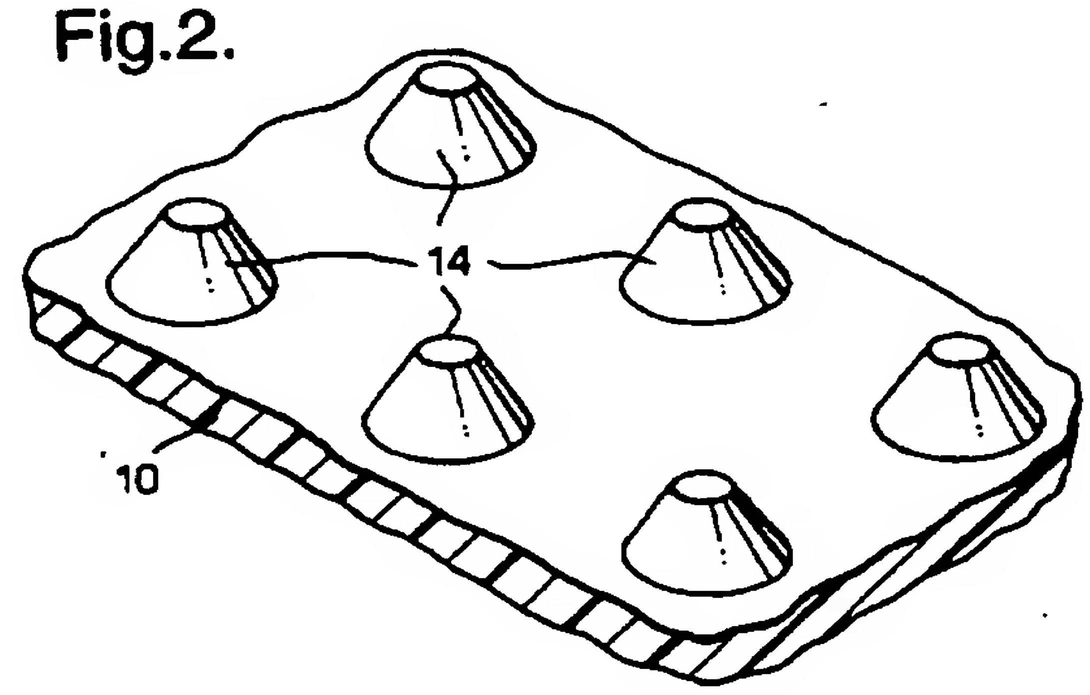
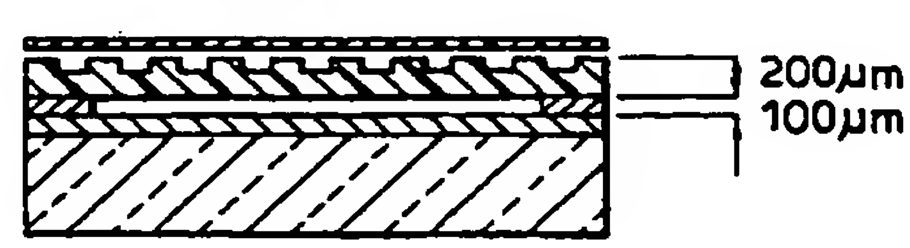


Fig.8.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

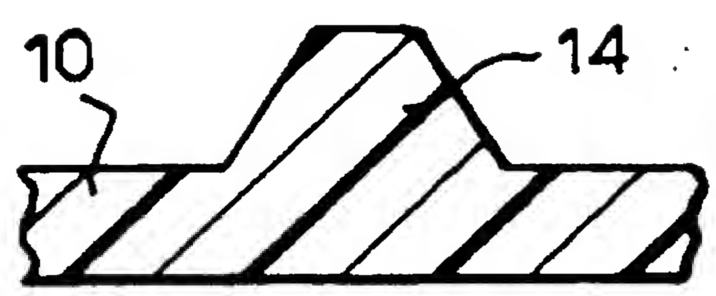


Fig.3.

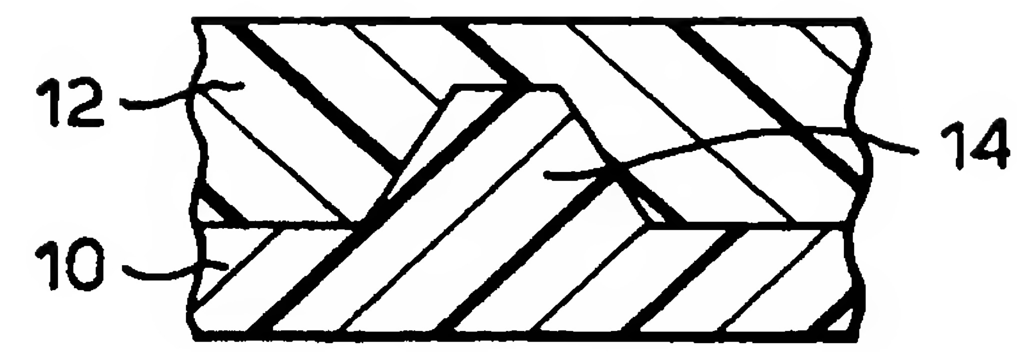


Fig.2.

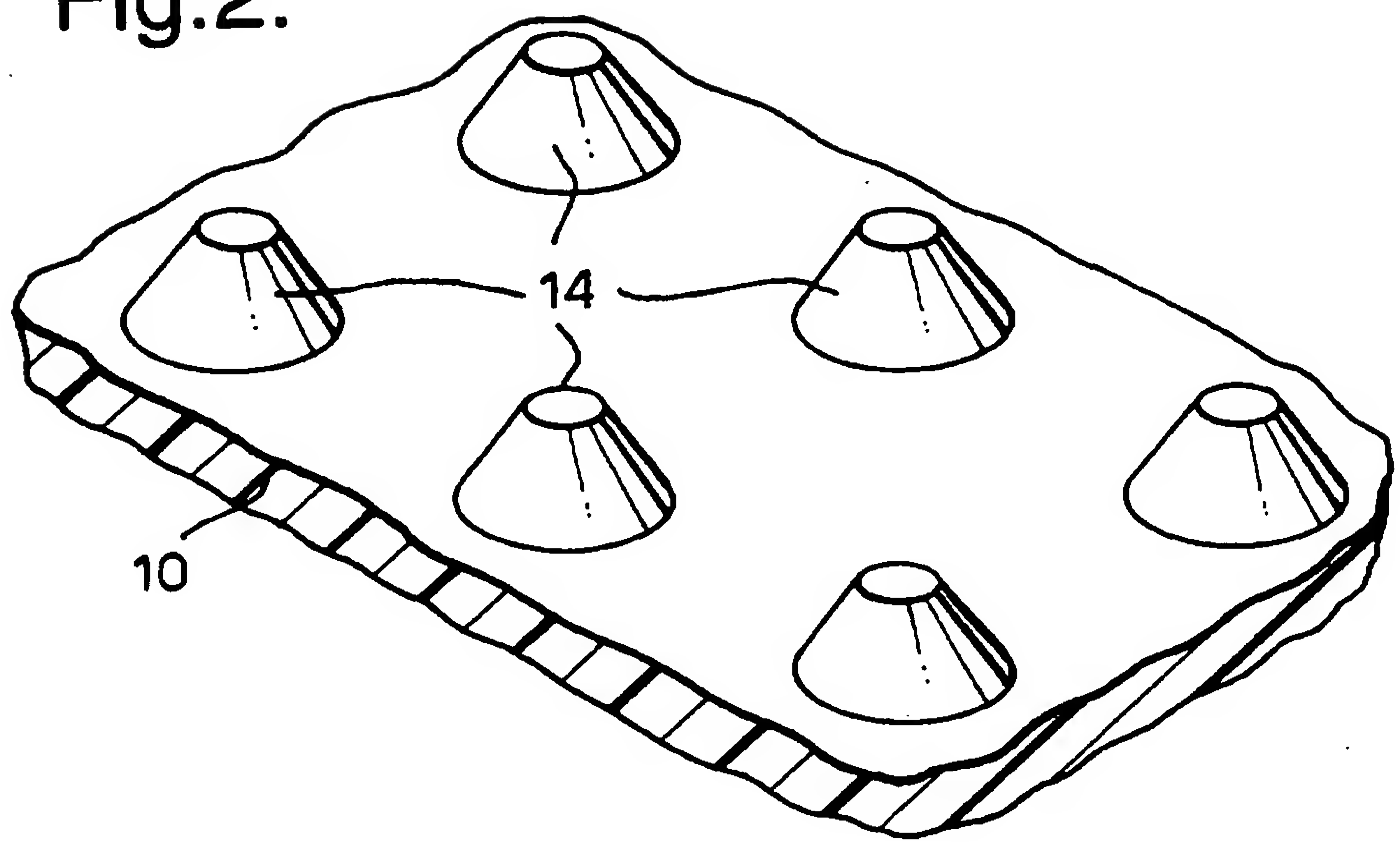


Fig.4.

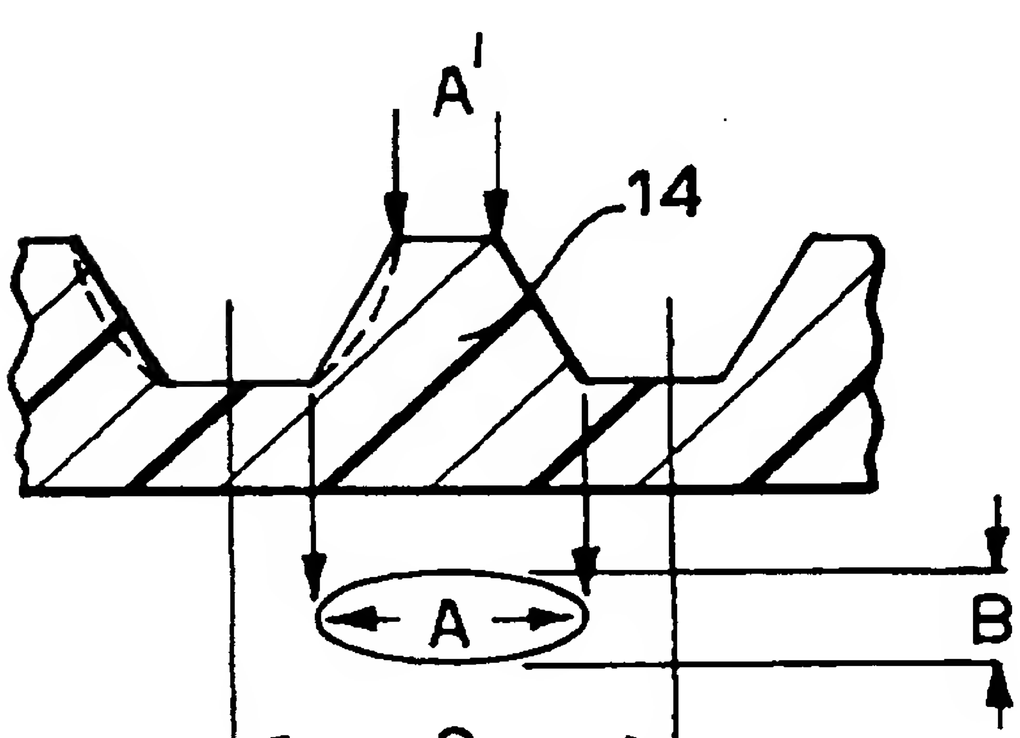


Fig.5.

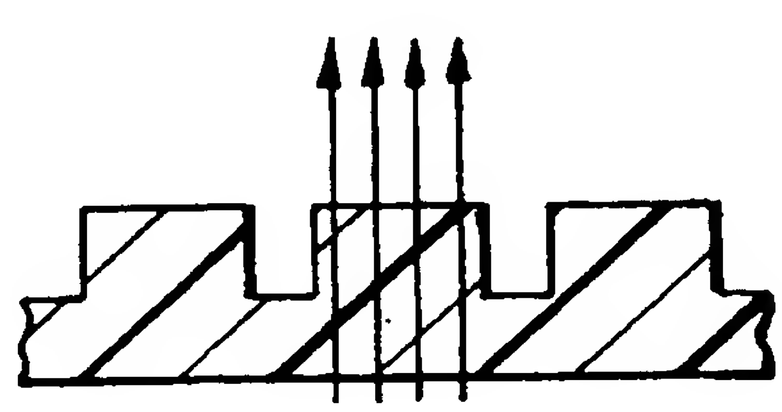


Fig.6.

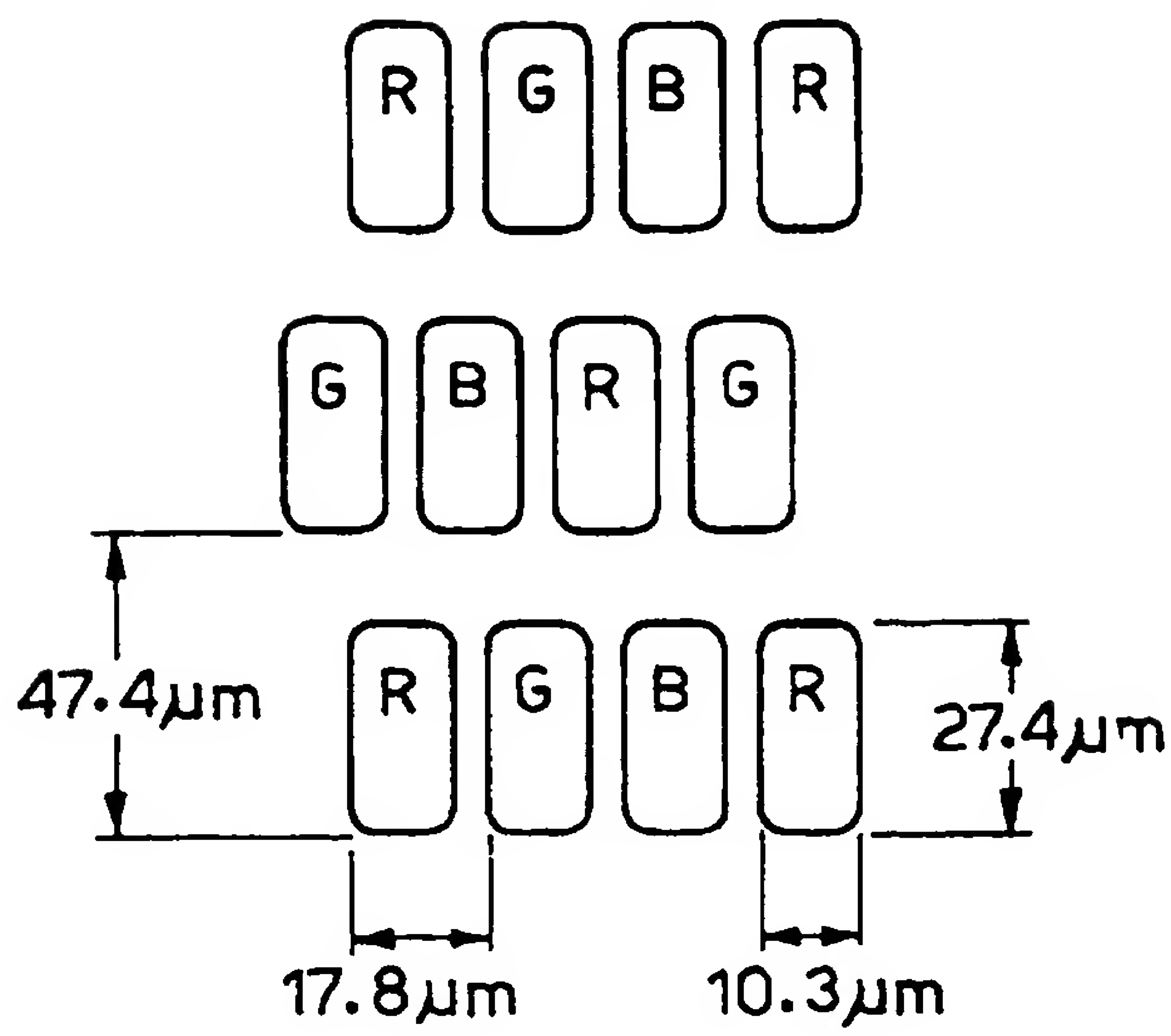


Fig.7.

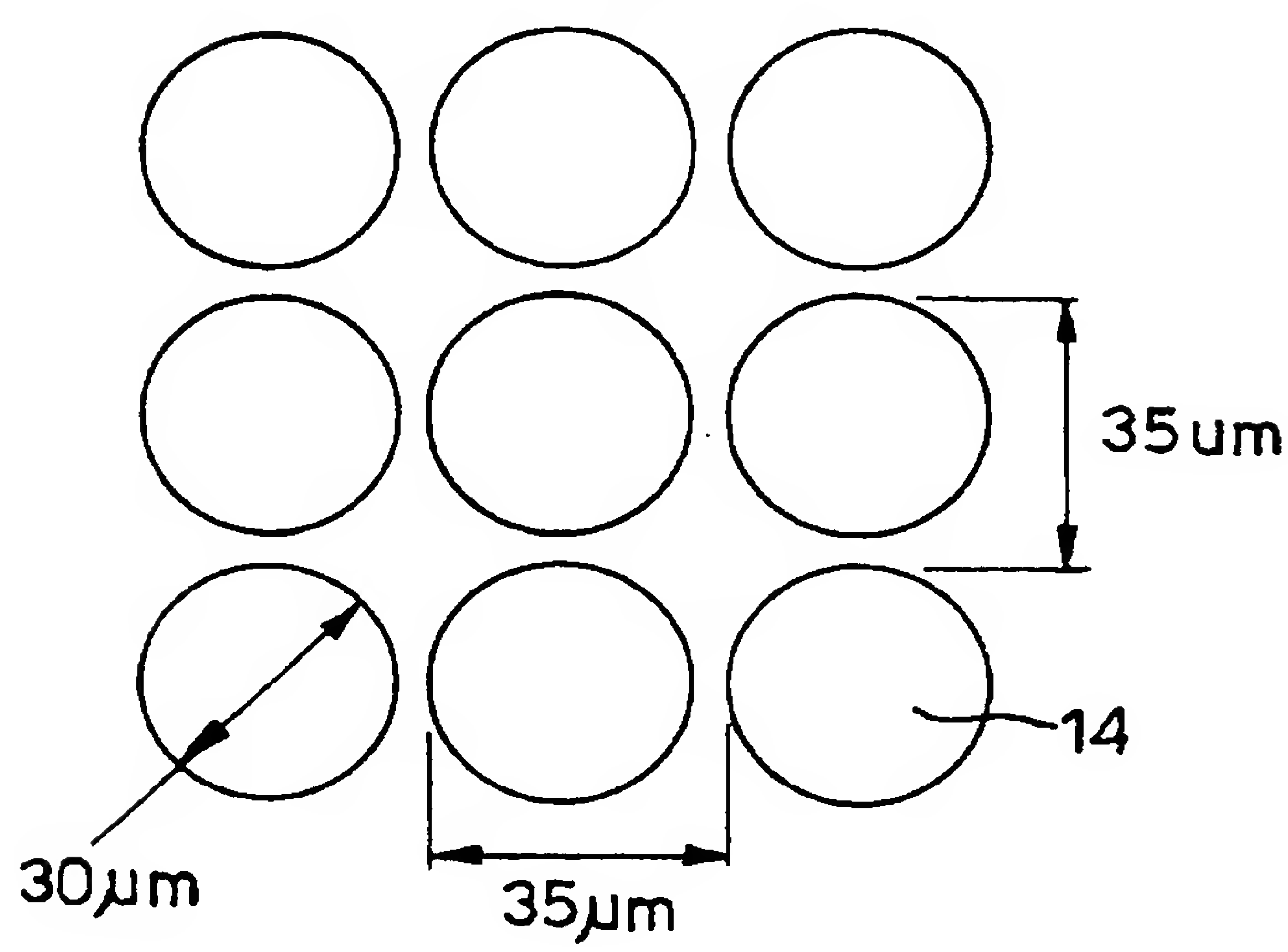


Fig.8.

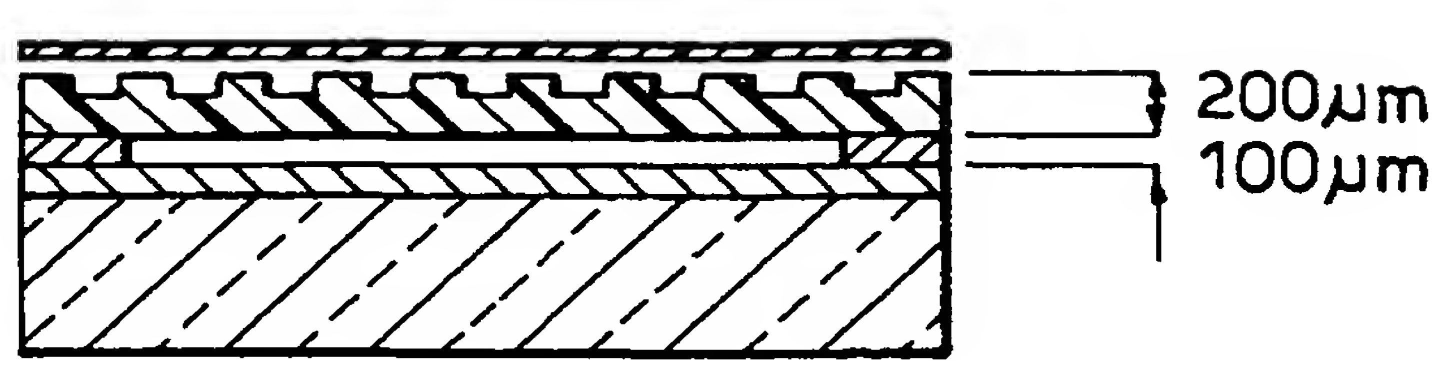


Fig.9a.

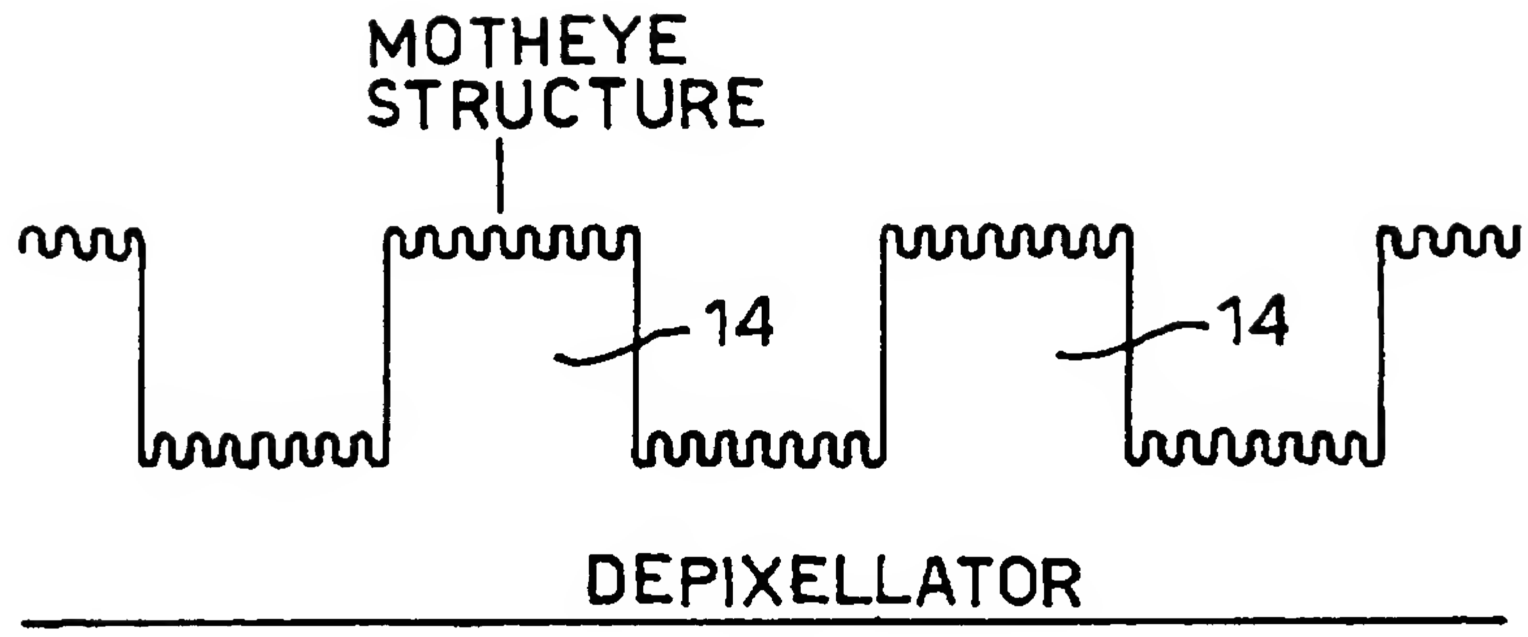


Fig.9b.

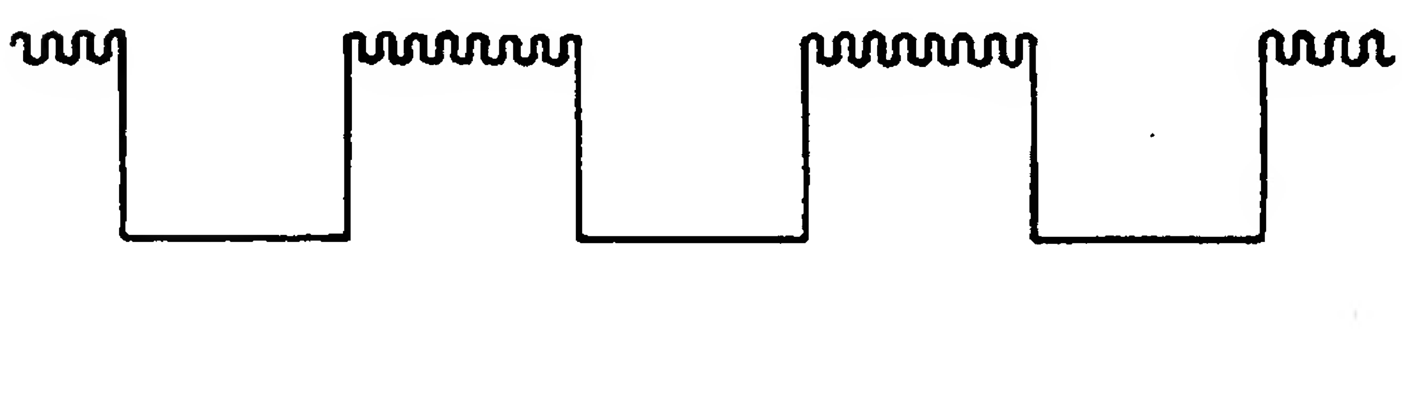


Fig.9c.

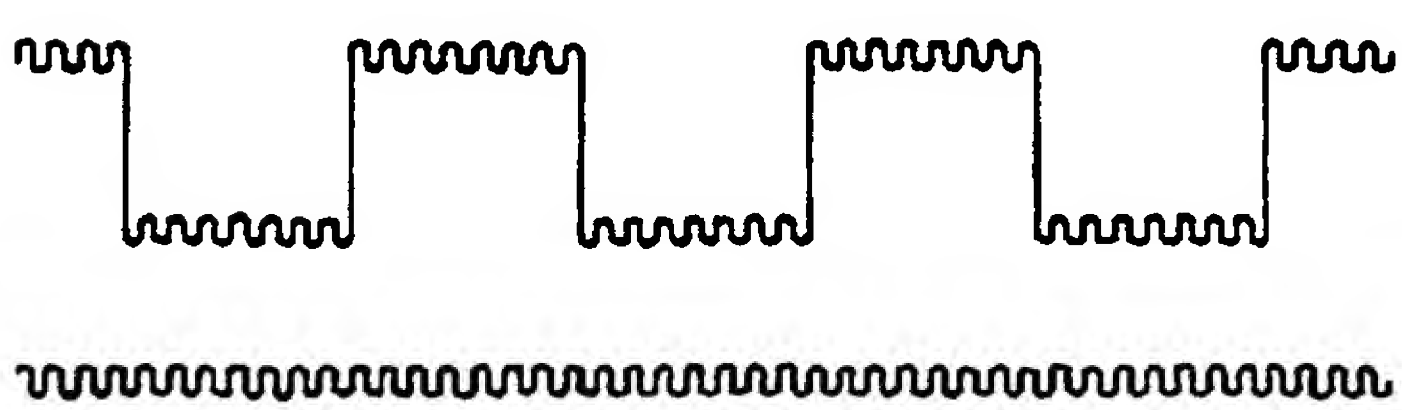
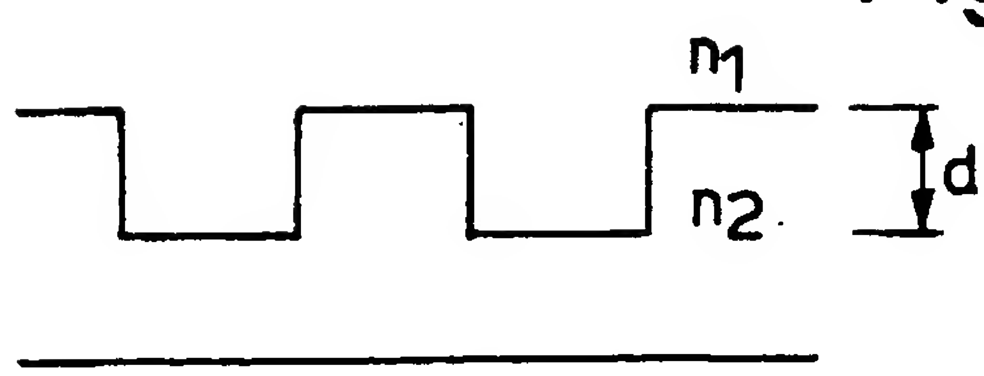
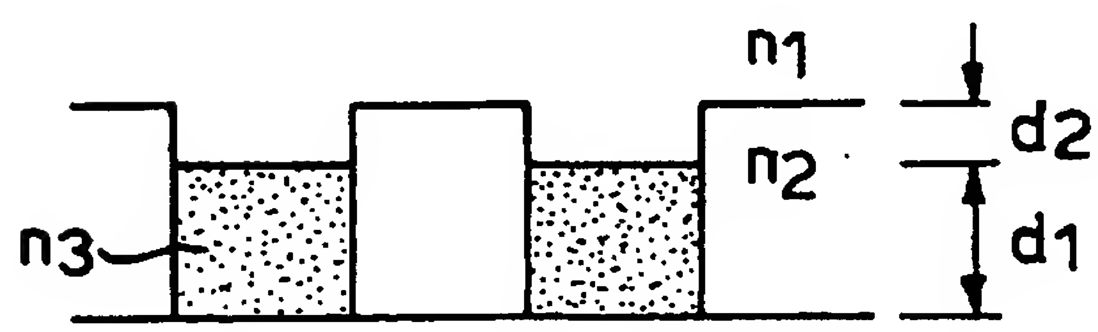


Fig.10.



If $n_2 > n_1$ then $\Delta = (n_2 - n_1)d$

Fig.11.



If $n_2 > n_3 > n_1$ then
$\Delta = (n_2 - n_1)d_2 + (n_2 - n_3)d_1$

Fig.12.

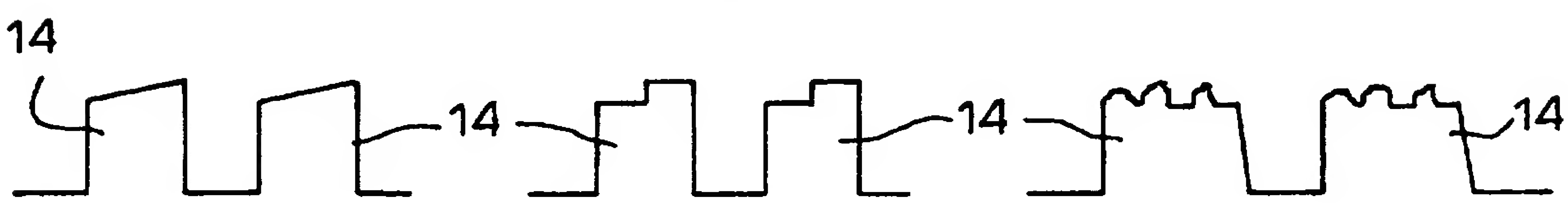


Fig.13.

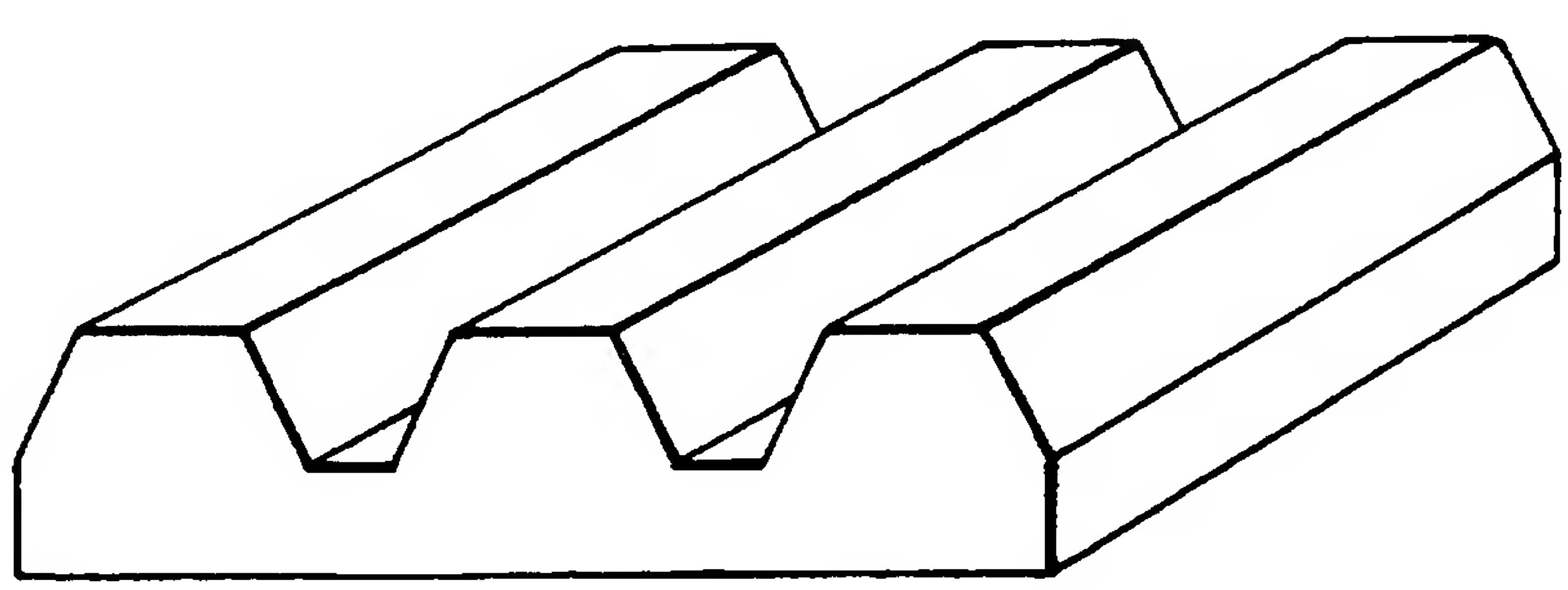


Fig.13A.

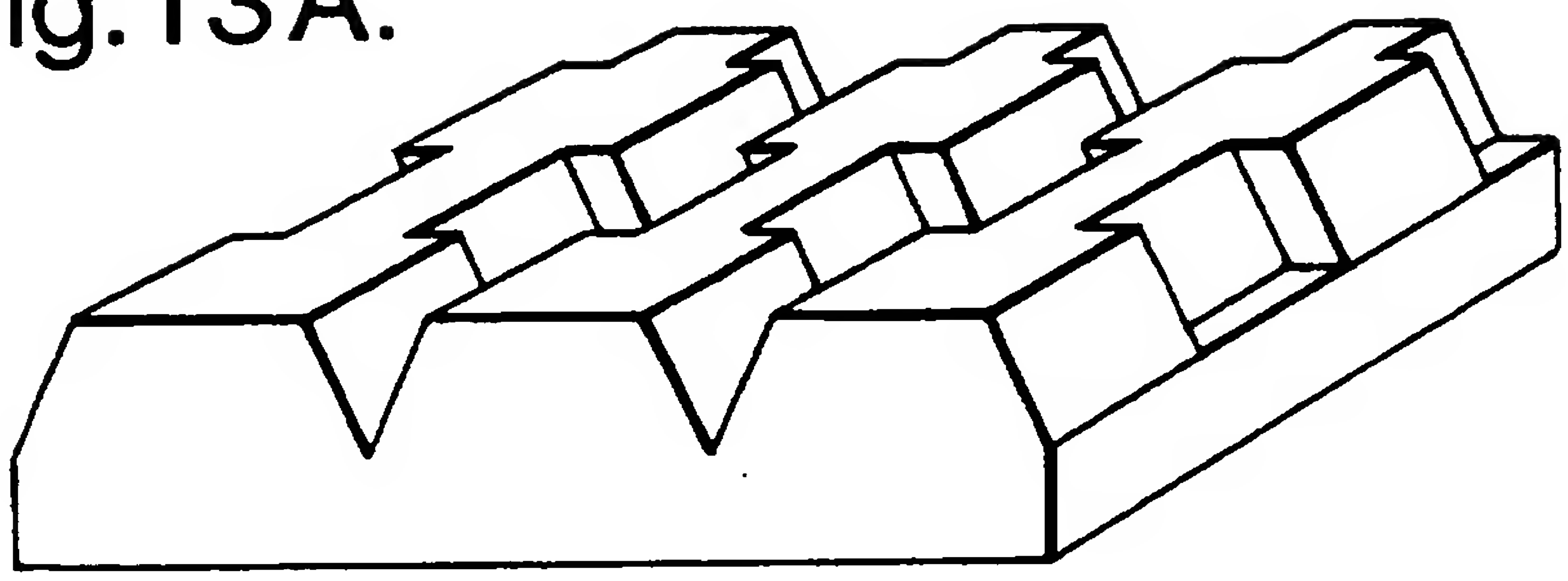


Fig.13B.

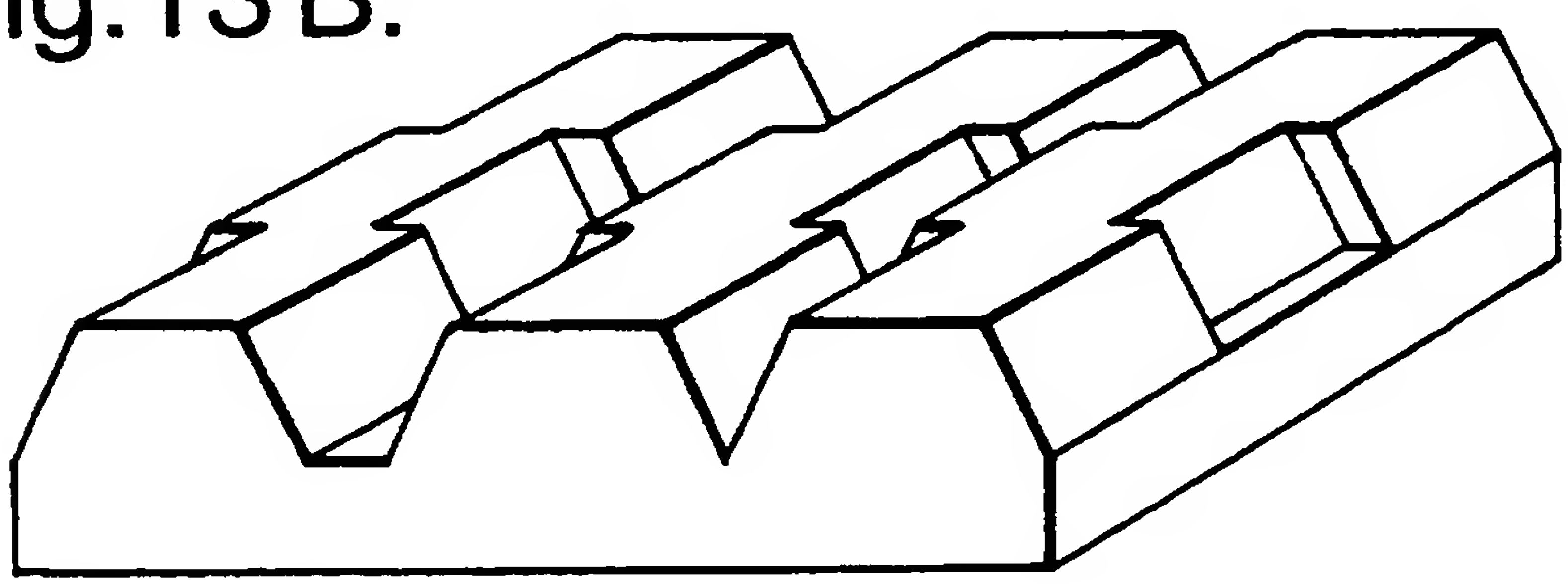


Fig.14.

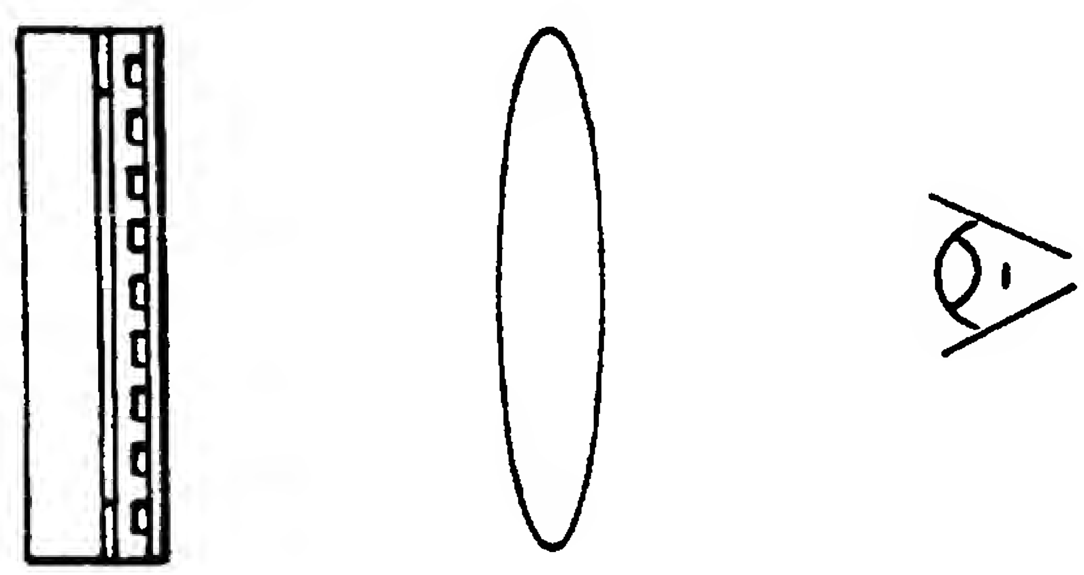


Fig.15.

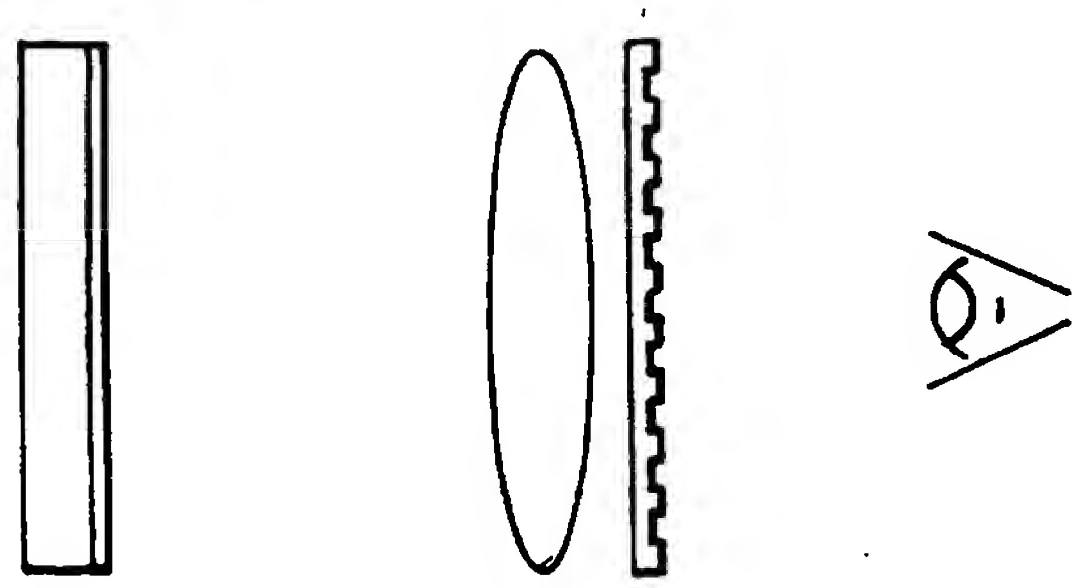


Fig.16.

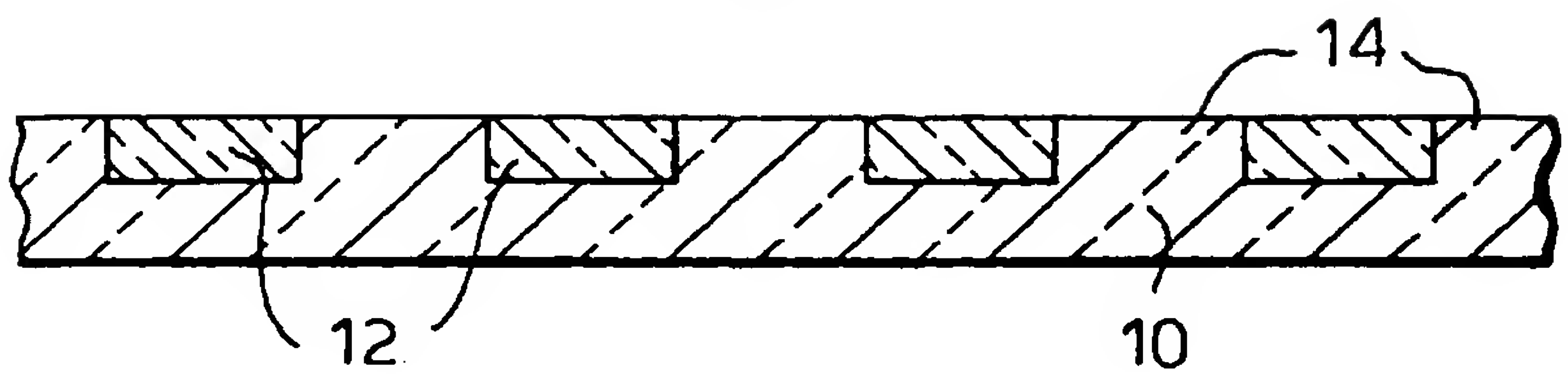


Fig.17.

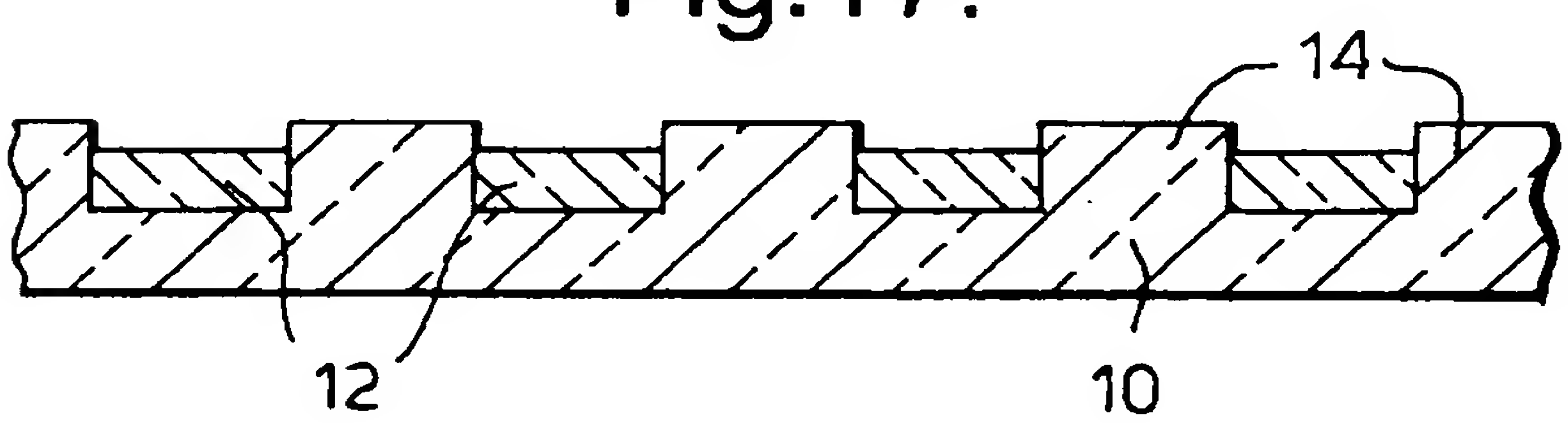


Fig.18.

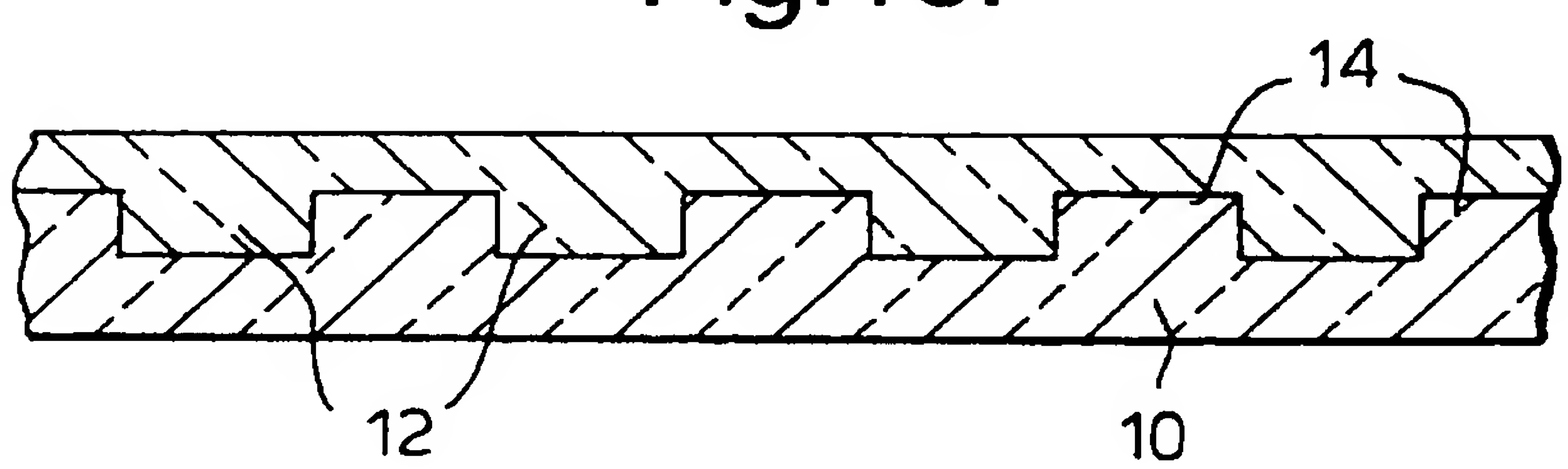


Fig.19.

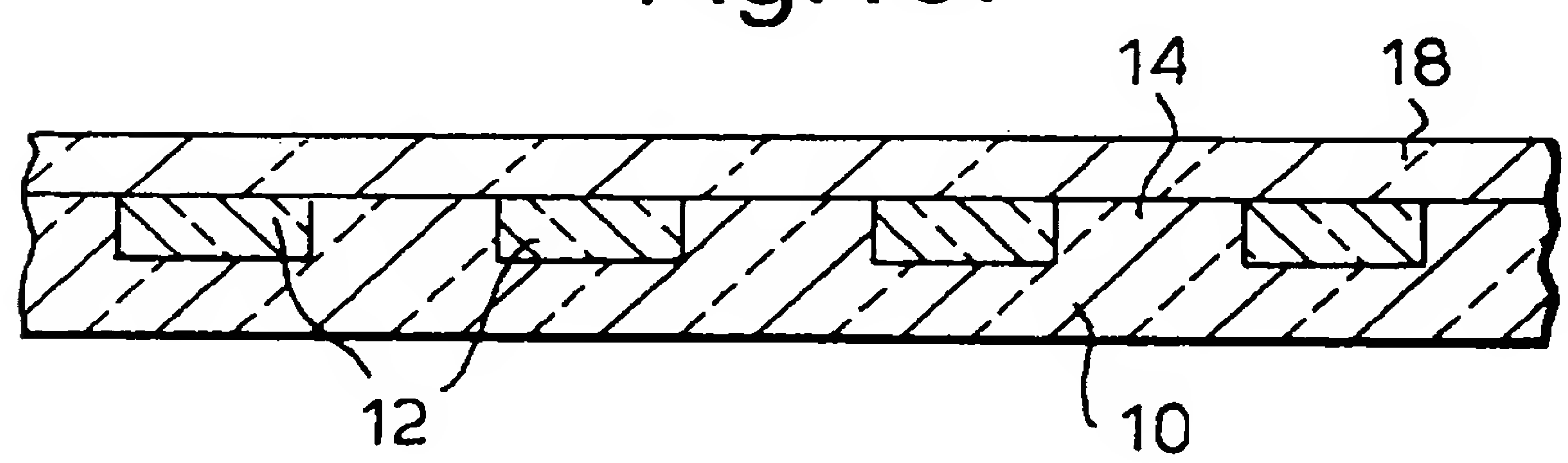
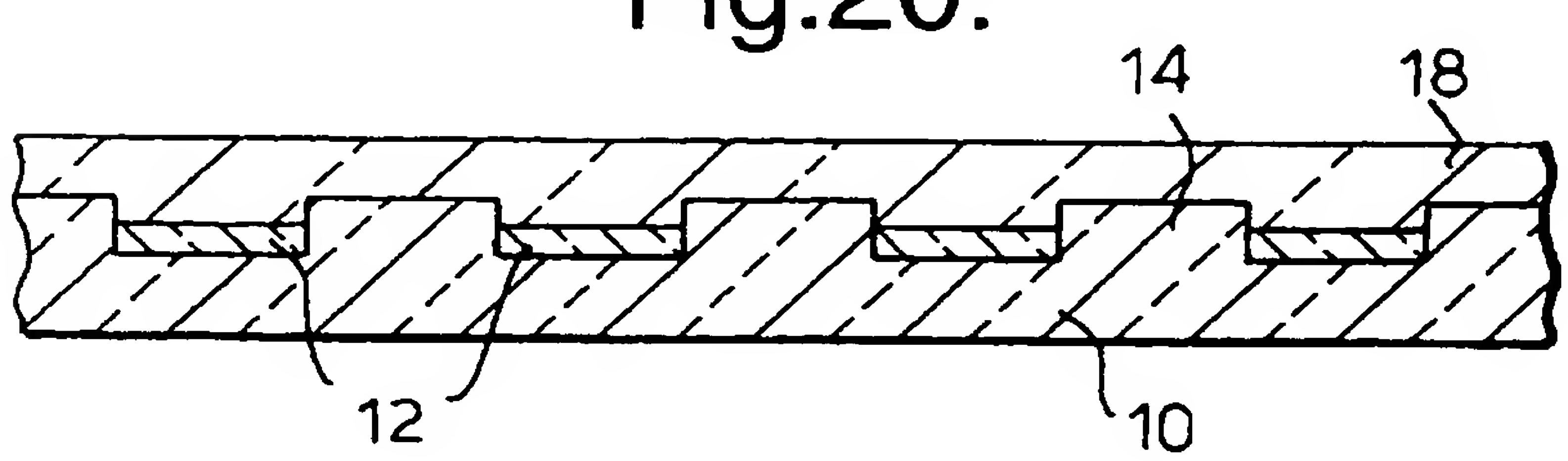


Fig.20.



2314943

PATENTS ACT 1977
Agent's Reference: P11579GB-H/JCC/ac

DESCRIPTION OF INVENTION

Title: "Improvements in or relating to light diffusers"

THIS INVENTION relates to optical diffusers such as may be used, for example, in front or rear projection screens or for collimating or depixelating screens for use in conjunction with pixelated LCD or other video display devices.

It is known to use screens of transparent material embossed or otherwise formed to provide arrays of small lenses as rear projection screens or as diffusers.

It is also known to use similar screens, placed in front of, for example, pixelated displays such as the LCD pixelated video displays used in portable computers or "pocket" televisions, or in head-mounted "virtual reality" displays to remove or reduce the observer's perception of the individual pixels and the inter-pixel bands, in such displays. The function of removing or reducing the perception of such pixels and inter-pixel bands is herein referred to as depixelation, and screens for this purpose are herein referred to as depixelating screens.

WO88/09957 and WO91/18304 disclose the use of screens comprising arrays of microlenses for depixelating pixelated LCD displays, i.e. for rendering less perceptible the individual pixels in such displays.

It is among the objects of the present invention to provide an improved optical diffuser.

According to one aspect of the invention there is provided a diffuser or depixelating screen comprising a sheet of light-transmitting or reflecting material incorporating an array of features characterised by relatively abrupt surface level or refractive index transitions at their boundaries.

In one group of embodiments, the diffuser or depixelator comprises a sheet of light-transmitting material having on at least one surface thereof a plurality of light-diverting or modifying structures each comprising a flat surface parallel with the plane of major extension of the sheet and a flank or wall extending from said surface to a perimeter spaced from the plane of said flat surface. By the term "flat surface" in this context is meant a surface in which surface irregularities, whether intentional or unintentional, are small in relation to the height or depth of the surface above or below said perimeter of the respective feature, for example a surface in which surface irregularities have a height less than 25%, more preferably less than 10% of the height or depth of the respective surface above or below said perimeter of the respective feature. It is well known that even apparently smooth and even polished surfaces exhibit irregularities at some scale, and, as will appear from what follows, in some embodiments of the invention, a predetermined texturing is imparted to relevant surfaces of depixelating screens to reduce reflectivity.

The flanks or side walls of the light-diverting structures may be perpendicular to said flat surfaces and to the plane of major extension of the sheet material or may be inclined with respect to said planes.

Said flanks of said light-diverting structures may comprise circular cylindrical or frusto-conical flanks or may comprise a plurality of plain faces or facets.

The light-diverting structures may be positive structures projecting from a base plane in the material to respective said flat terminal surfaces or may be negative structures in the form of recesses extending, from a base plane comprising an outer surface of the sheet material, inwardly into the material, with said flat surfaces lying at the bottoms of said recesses. Of course, the diffusing sheet material may comprise a combination of positive and negative structures of the kind referred to.

The light-diffusing material may be adapted to operate by refraction of light rays to said flanks and/or said end faces and/or by total internal reflection of at least certain rays by said flank surfaces.

In some embodiments of the invention, the surface of the sheet material bearing said structures may be covered by a layer of a material of different refractive index, filling the recesses defined between or defined by said structures and presenting, for example, a planar outer surface. Said further material of different refractive index may, however, itself be formed with such structures as referred to above on the surface thereof remote from the first material.

In a further variant, two sheets of light-diffusing material, each having such light-diverting structures on one surface thereof may be arranged structured surface to structured surface, for example with the regions not occupied by the structures of either sheet being filled by

a light-transmitting material of a different refractive index.

According to another aspect of the invention, there is provided a depixelating material, as herein defined, comprising a sheet bearing an array of light-diffracting structures.

According to yet another aspect of the invention, there is provided a video or the like display comprising an imaging apparatus which, in operation, provides a regular array of image-forming elements or pixels, with intervening non-image forming elements and further comprising a depixelating material according to the above aspect having a similar regular array of light diffracting features spaced from the image surface of said array of image forming elements or pixels, the dimensions and spacing of said pixels or image forming elements, the dimensions and spacing of the light-diffracting structures and the spacing of the array of light diffracting features from said array of pixels or image forming elements being such that, to an observer of the display, the inter-pixel or picture element spaces are rendered imperceptible by diffracted light emanating from the neighbouring pixels or picture elements.

Embodiments of the invention are described below by way of example with reference to the accompanying drawings in which:-

FIGURE 1 is a schematic sectional view, to an enlarged scale, perpendicular to the plane of major extension of part of a light-diffusing sheet embodying the present invention,

FIGURE 2 is a perspective view, also to an enlarged scale, of part of the light-diffusing sheet of Figure 1,

FIGURE 3 is a view, similar to Figure 1, of a variant,

FIGURE 4 is a diagram illustrating various variables of a screen of the type illustrated in Figures 1 and 2,

FIGURE 5 is a view corresponding to Figure 1 but of a further variant,

FIGURE 6 is a schematic fragmentary view of a pixelated LCD display,

FIGURE 7 is a schematic fragmentary view of a diffracting depixelating screen embodying the invention,

FIGURE 8 is a schematic sectional view of a video display incorporating a pixelated LCD display and a depixelating screen according to the invention,

FIGURES 9a to 9c are schematic views similar to Figure 5 of variant depixelating screens including anti-reflective relief texturing,

FIGURES 10 and 11 are further schematic sectional views of depixelating screens embodying the invention,

FIGURE 12 shows, in schematic sectional view, further configurations of depixelating screen,

FIGURE 13 is a perspective view illustrating a yet further configuration of depixelating screen,

FIGURES 13A and 13B are perspective views similar to Figure 13 but showing variant forms of depixelating screen,

FIGURE 14 illustrates the use of a depixelating screen in a head-mounted display, and

FIGURE 15 is a schematic view, similar to Figure 14, showing an alternative arrangement, and

FIGURES 16 to 20 are schematic sectional views of yet further configurations of depixelating screens embodying the invention.

Referring to Figures 1 and 2, in one embodiment of the invention, a light-diffusing material comprises a sheet 10 of transparent plastics having, projecting from one major surface thereof, an array of similar frusto-conical formations 14 integral with the sheet. Each formation 14 has a flat top surface which is parallel with the plane of major extension of the sheet 10, e.g. parallel with the base surface of the sheet and with the surface from which the formation 14 projects.

In the variant illustrated in Figure 3, a further light-transmitting material 12 of a different refractive index from the first sheet 10 is superimposed, for example, is cast, over the upper surface of the sheet 10 so as to cover the formations 14 and fill the regions between adjacent formations 14. Whilst in the arrangement illustrated in Figure 2, the formations 14 are frustums of cones with right circular bases and presenting flat upper faces parallel with the major plane of the sheet but spaced therefrom, the formations 14 may be of other forms, for example, they may be frustums of cones based upon ellipses (cf. Figure 4) (i.e. with elliptical bases and elliptical upper surfaces) or based on other shapes, including, for example, regular or irregular triangles, quadrilaterals or

polygonal shapes. Thus, for example, the formations 14 may be frusto-tetrahedral or frusto-pyramidal.

In Figure 4, the length of the major axis of the elliptical base of formation 14 is indicated at A and that of the minor axis at B. The length of the major axis of the smaller upper face of formation 14 is indicated at A'. The reference C represents the width of the "cell" of the pattern (assumed to be regular if C is to have significance), which contains the single formation 14. It will be appreciated that certain characteristics of the structures 14 can be defined in terms of ratios between selected quantities among those mentioned. For example, the aspect ratio may be defined as the ratio A:B (corresponding to the eccentricity of the ellipse where the structure is ellipsoidal), the ratio A:A', representing the extent to which the formation resembles a cylinder, at one extreme, or a cone, at the other, the ratio A:C which is a measure of the density of "packing" of structures 14 on the sheet, and so on. Different light diffusing characteristics may be specified by reference to these ratios.

Where the features 14 have a significantly greater dimension in one direction in the plane of the sheet than in an orthogonal direction, i.e. where the aspect ratios of the features 14 are significantly different from unity and the longer transverse dimensions of the features are aligned along a predetermined direction in the plane of the sheet, or tend towards such alignment, a corresponding asymmetry in the diffusing characteristics of the product is noted. That is to say, the angle of view, in a plane containing the direction of least extension, tends to be substantially greater than in a plane containing the direction of greatest extension.

Whilst, in the preferred embodiment, the formations are frusto-conical or frusto-pyramidal in form, said flanks may be convexly or concavely curved in vertical planes through the centres of the formations, for example as illustrated by the curved broken lines in Figure 4.

Referring to Figure 5, in a further form of diffuser embodying the invention, each formation comprises a flat upper surface parallel with and spaced above a flat inter-formation surface of the sheet, the side walls or flanks of each formation extending vertically, perpendicular to the planes of the upper faces thereof.

Whilst, as described above the features 14 are entirely surface relief features, analogous features may be produced by refractive index gradations within the sheet or may comprise both surface relief features and refractive index variations. By way of example, features including surface relief components and graded refractive index components may be produced by selective exposure, through an appropriate optical mask, of a photopolymerisable medium to actinic light. Indeed a similar technique may be used for producing principally surface relief features although conventional techniques such as embossing or casting may also be used. Significant parameters are feature size, shape and 2D distribution (Arrays of such features may be regular or random). For certain applications, a single sheet 10 may include features of differing shapes and sizes and distributions. It is also possible to superimpose a plurality of diffuser sheets so that the formations on each sheet are superimposed on corresponding formations of the sheet or sheets below. In such an arrangement, the formations may or may not be of the same shape.

The diffuser of Figure 5 may be regarded as a surface relief phase structure, generating discontinuities in wave-fronts in light passing through the structure, (due to the difference in light velocity in air and in the medium of the screen) with consequent diffraction. As the structure of Figure 5 produces its effect due to the refractive index difference between the sheet material, in the raised formations, and the regions, between such formations, filled with air, a similar effect is obtainable in variants in which the regions between such formations are filled with, for example, a solid transparent medium such as transparent plastics, of a refractive index different from that of the base sheet material. Thus a similar structure may be produced by forming holes through a transparent sheet material of a first refractive index, for example by machining, chemical etching, ion beam etching, laser ablation etc. and filling such holes with transparent material of a different refractive index (or indeed by leaving such holes unfilled) to form a volumetric phase structure. A similar structure may be formed by selective exposure of a photopolymerisable material to polymerising radiation, for example by exposing an array of spots on a sheet of such material, or by exposing the entire material except in an array of spots to form cylinders or "islands" in the medium which have a higher or lower refractive index than the remainder of the medium.

The array of features in the arrangement of Figure 5 is substantially regular, for example in the form of substantially regularly spaced rows and columns of such features so that the substantially regular array of features acts in a manner analogous to a diffraction grating. With the diffuser of Figure 5 arranged in front of, for example, an LCD pixelating display and with appropriate spacing of the array of features 14 from the

pixel image plane, an observer viewing the screen will, in effect, see, in addition to zero order images of the pixels, first, second and subsequent order images of the pixels partially superimposed on each other and on the zero order images, and thereby extending into or across the inter-pixel spaces (which are normally black in LCD pixelated displays). Because only a relatively small region of the diffraction screen over and around each pixel is responsible for the greater-than-zero order images contributing to the light reaching the observer's eye from the vicinity of that pixel, variations in the spacing of the rows and columns of features 14 over the width and height of the screen are relatively unimportant provided that the spatial rate of variation is not too rapid. Similar effects are obtainable with depixelating screens comprising similarly regular arrays of features 14 over the form illustrated in Figures 1 to 4 and it is inferred that these screens likewise owe their effect to a diffraction grating-like action. Accordingly analogous diffraction screens, including, even, screens which are opaque except for regular arrays of light-transmitting apertures or which are transparent except for regular arrays of opaque spots may be similarly effective.

Figures 6 to 8 illustrate the use of a diffracting array screen for depixelating an LCD pixelated screen, illustrated in Figure 6, comprising horizontal rows and vertical columns of pixels, each 10.3 μm by 27.4 μm, with an inter-pixel horizontal spacing of 7.5 μm and a vertical inter-pixel spacing of 20 μm thus with horizontal pitch of 17.8 μm between pixels and a vertical pitch of 47.4 μm. As illustrated in Figure 7, an appropriate diffractive array comprises horizontal rows and columns of features 14 (circular in plan in the example shown) at a horizontal and vertical pitch of 35 μm, the features being 30 μm in

diameter and the spacing between adjacent features being 5 μm, giving a pitch of 35 μm. Referring to Figure 8, the diffusing depixelating screen is so located relative to the image plane of the pixelated LCD screen as to establish a spacing of 300 μm between the image plane and the formations 14. Figure 8 also illustrates the use of spacers at the edges of the screen to establish the appropriate spacing.

In general there is a relationship between the mean wavelength of the visible light concerned, the inter-pixel spacing, the pitch between formations 14 and the spacing between the depixelating screen and image plane of the LCD screen.

To ensure the correct value of such spacing various measures may be adopted.

Thus, spacers or gaskets may be used between the LCD screen and the depixelation screen as illustrated in Figure 8 to obtain the correct distance and also to remove Moiré interference. The depixelator may be used both above and below the analysing polariser in an LCD and within the optical system.

It will be understood that by making the transparent sheet incorporating the diffraction formations 14 of the appropriate thickness such sheet may also be made to serve as its own spacer.

In general, the dimensions and spacing of the features 14 should be such, in relation to the display pixels, that each feature 14 can span two pixels, in the case of a colour display of the kind illustrated in Figure 6 having three pixels (Red, Green and Blue) for each

picture element. The spacing between features 14 should be somewhat less than the smallest inter-pixel spacing. In a monochrome arrangement, using a monochrome LCD pixelated display where each pixel corresponds to a respective picture element, the features 14 may advantageously be somewhat smaller, for example such that each feature 14 spans around 1½ pixels. The features 14 may, as indicated above, be elongate, for example elliptical as viewed in plan (rather than circular as in Figure 7) and/or the spacing between adjoining features may be greater along one axis in the plane of the screen than along a perpendicular axis, so as to obtain different angles of diffraction in orthogonal directions. Such a measure may serve, for example, to optimise a depixelating screen for use in conjunction with pixel arrays having elongate pixels and/or different pixel spacings horizontally and vertically.

With careful design, Moiré fringing should not be a problem. However, unwanted reflections from the depixelator sheet may cause fringe formation due to regions of unequal separation of the depixelator from the LCD surface. For this reason spacers or gaskets may be used to separate the depixelator from the LCD surface by an amount much greater than the coherence length of light. A wedged spacer helps further by producing fringes with a spatial frequency greater than the display, thus neutralising their effect. This technique could potentially be useful in displays with large coherence lengths, such as surface emitting laser diode displays, for example.

An improved solution might be to add an anti-reflective coating to the side of the depixelator nearer to the LCD to reduce unwanted reflections and improve contrast. Alternatively, surface relief structures can be incorporated to induce anti-reflective effects. A degree

of reflection suppression can be produced by setting the heights of the pedestals (i.e. features 14) equal to an integral odd number of half wavelengths of the incident light. A more effective method would be to incorporate a moth-eye structure. A moth-eye structure can be produced in a photo resist, for example by exposing the latter to the pattern resulting from the interference of four crossed laser beams in photoresist to produce a series of close-packed small domes less than half a micron in diameter. A hybrid depixelator/anti-reflective structure is shown in Figure 9a. A similar moth-eye structure could, alternatively or additionally, be produced in the surface of the depixelating screen remote from the formation 14, as shown in Figures 9b and 9c.

It will be understood that the size of the surface relief structures forming the moth-eye structure, in relation to the dimensions of the features 14 is somewhat exaggerated in Figures 9a to 9c. If the moth-eye features are 0.5 μ in height and the features 14, say 30 μ in height, the height of the moth-eye features is less than 2% of the height of the features 14, so that the features 14 are still substantially flat-topped.

In general, as indicated above, a feature 14 is to be regarded as flat-topped if any sub-features thereon are, in height, less than 25% of the height of the features 14, although it is preferred that any such sub-features should be less than 10% of the height of features 14.

As noted above, a diffractive depixelating screen can be formed by punching shaped holes through the depth of a laminar light-transmitting medium. This might be done by laser ablation (direct writing or via HOE), selective-ion etching or chemical etching through a lithographic mask or

deposited pattern, e.g. by screen printing. Other methods are also available. Another example of laser ablation being used to create the depixelator would be to write on the surface of the glass or plastic cover of an LCD. If, prior to assembly, the top cover of the LCD was coated with a suitable material (with the same refractive index as the cover plate) that coating could be selectively ablated whereby the cover of the LCD would incorporate the depixelator. This technique would do away with the need for gaskets.

The screen configurations described above are merely examples of a great variety of depixelating or diffusing screen configurations which may be utilised. Thus, as regards the profile of the individual features 14 (i.e. as viewed in section perpendicular to the plane of the sheet material), virtually any profile may be appropriate in some case, so long as the dimensions of the feature and its distribution can be controlled. Specifically, the upper surface does not need to be flat or parallel with the plane of major extension of the sheet, although this is currently the preferred configuration. Figure 12 shows examples of profiles which might be effective. The distribution of the features 14 could be entirely random, or repeated random patterns, or regular arrays of patterns. The features 14 may or may not have the same distribution over the entire display area. However, it is currently preferred that the array of features 14 should be substantially regular, or that, at least, the spatial frequency of any departure from regularity over the width or height of the depixelating screen should be low in relation to the spatial frequency of occurrence of features 14, so that any change in spacing between features 14 from one side of the screen to the other, for example, is very gradual.

As a further example, the features 14 might be pointed rather than flat-topped, for example conical, rather than the frusto-conical form shown in Figure 1.

Figure 10 illustrates a fragment of a depixelating screen in which the features 14 are defined by surface profiling and Figure 11 a fragment of a screen in which the features 14 are defined partly by surface profiling and partly by refractive index variations.

The diffractive effects are achieved by selecting an appropriate feature size and distribution and by using surface relief and/or volume refractive index differences to delineate the features 14. Figures 11 and 12 illustrate how diffracting depixelating screens produced by different techniques can nevertheless be made to have very similar performances by choosing appropriate values for refractive indices (n_1, n_2, n_3, etc). and profile dimensions such that the overall optical path length difference Δ between either side of the respective discontinuity is comparable.

Thus, if a structure such as illustrated in Figure 10 is embossed in polycarbonate ($n = 1.58$) and has a formation depth $d = 0.7\ \mu m$, then the optical path difference, if n_1 is that of air, is 406 nm.

It is clear that by choosing the dimensions and material properties the optical path difference can be made equal to the relief-only case. The resulting structure could be either entirely volumetric in nature, with the sheet having flat parallel faces, or a combination of volume and relief effects. The material could also be perforated such that n_3 in Figure 11 is the refractive index of air. The principle can also be extended to include variations in relief on both surfaces.

The technique described above with reference to Figure 3 in which a further light-transmitting material of a different refractive index is cast, or otherwise superimposed, on the profiled surface of sheet 10 providing the diffractive array can be used to provide diffractive diffusers of any of a useful range of characteristics, by appropriately selecting the depth of the layer of said further light transmitting material 12. Thus, for example, as shown in Figure 16, the upper surface of the further light-transmitting material 12 may be flush with the upper surfaces of features 14, or, as shown in Figure 17, the upper surface of the further light-transmitting material 12 may be below the upper surfaces of the features 14, thus affording an arrangement similar in effect to that of Figure 11. It will be understood that where the discrete light-diverting structures are negative structures, in the form of recesses or pits, extending into the sheet 10 from the base plane, rather than projections as illustrated in Figure 1, the material 12 of different refractive index may only partly fill each said recess or pit, i.e. to a level below the base surface, or may just fill each said recess or pit, i.e. to the level of said base surface. Furthermore, where, as exemplified above, the features 14 are pointed rather than flat-topped, the material(s) of different refractive index may extend around features 14 only to an intermediate level with the tips of the formations 14 projecting above such material.

In any of the above variants, the material(s) 12, 17 of different refractive index applied over the base sheet 10 may be of a refractive index less than or greater than that of the material of the base sheet 10, according to the particular effect required.

It will further be appreciated that further modification of the properties of the diffractive screens may be effected by superimposing two or more materials of different refractive indices from one another on the profiled surface of the base sheet 10, so that, for example, as illustrated in Figure 19, such a material 12 of a first refractive index different from that of the base sheet 10 may be applied to a level corresponding to the upper surfaces of the formations 14 and a layer of a material 18 of a second refractive index, different from that of the base sheet 10 and the directly overlying material, may be applied over the upper surfaces of the formations 14 and the upper surface of material 12.

Likewise, as illustrated in Figure 20, a material 12 of a refractive index different from base sheet 10 may be applied to a level below the upper surfaces of the formations 14 and a material 18 of another refractive index applied over the material 12 to a level equal to or below the upper surfaces of the formation 14 or may be applied over the formations 14 and over the material 12, i.e. to a level above the upper surfaces of formations 14. In the same way, three or more layers of different refractive indices may be applied over the base sheet 10. It will be understood that corresponding variations are possible where the light diverting formations are negative formations, i.e. recesses or pits formed in the base sheet 10, rather than projections. Thus, the pits may be wholly or partly filled with a material (other than air) of a different refractive index from the material of the base sheet 10, or with superimposed layers of two or more materials of different refractive index, or the recesses or pits may be filled or partially filled with one such material and the whole covered with a layer of a different refractive index, and so on. Preferably the materials 12, 18, of different

refractive indices will be transparent plastics materials. The properties of the diffractive diffuser which are apt to be modified by the application of material of a different refractive index or indices include such properties as the tendency of the screen to reflect light from the surroundings (which generally reduces contrast).

In further variants a second light-transmitting material of a refractive index different from that of air and of the base sheet 10 may be applied to the surface of the sheet 10 bearing the structures 14 in strips, blocks, or islands which do not simply follow (i.e. correspond with or register with) the structures 14 but may, for example, extend partly across the structures 14 and partly over the intervening base surface, or may form fine scale relief features intervening between the structures 14. Similarly, where the second light-transmitting material forms a continuous layer over at least the base surface of the sheet 10 from which the structures 14 extend, the continuous exposed surface of said second material may itself be configured to afford relief structures which may, like the structures 14, be relatively abrupt-edged or may, alternatively, be in the form of convex or concave lenses, for example spherical or cylindrical lenses, to afford an enhanced diffusive effect. Similarly, the second material overlaid on the base surface of sheet 10 may be a graded-refractive index material in which the refractive index variations define an array of graded refractive index microlenses, or define other light modifying structures, and these microlenses or other structures may correspond with and register with the structures 15 or may be graded refractive index lenses or other structures which bear no simple correspondence with the structures 14 or register completely therewith.

By placing two or more sheets on top of one another similar optical path differences and diffractive effects can be achieved, for example sheets could be placed structured surface to structured surface or structured surface to unstructured surface.

In some cases it may also benefit the display to depixelate in one direction only, for instance when the pixels are arranged in columns or rows of the same colour. Thus for such an application a depixelator (of uniform refractive index) may be formed with a series of continuous parallel ridges or furrows as illustrated in Figure 13 constructed of continuous lines of "ridges" or "furrows".

In variants of this arrangement, the ridges or furrows, whilst exhibiting overall parallelism, may each be laterally modulated, in width and/or transverse location, in a regular pattern which is repeated throughout each rib. For example, an arrangement such as illustrated in Figure 13B may be adopted where successive rows of pixels are staggered with respect to the preceding rows. In the arrangement of Figure 13B, each ridge effectively follows a "square wave" pattern, but in further variants each ridge may follow some other repeating "waveform" such as a sinusoidal waveform. In further variants such as that shown in Figure 13A, each ridge or furrow may have a lateral configuration which is symmetrical about a medial or centre line of the ridge, so that each ridge is, for example, alternately wider and narrower. The configuration of the ridges or furrows need not bear any close relationship with the arrangement of the pixels. Indeed a varying rib boundary such as illustrated in Figures 13A and 13B may principally serve to "break up" the normally linear inter-pixel spaces and thereby contribute to the elimination of perception of pixels.

Figure 14 illustrates an arrangement in which the depixelating sheet or array is provided under the polariser in the LCD display. The configuration shown in Figure 14 is represented, schematically, as being incorporated in a head-mounted display (HMD) in which a pixelated LCD display is arranged relatively close to the viewer's eye and an optical system is interposed between the display and the viewer's eye to present, to the viewer's eye, an enlarged virtual image of the LCD display at an appropriate viewing distance. The configuration illustrated in Figure 14 can provide improved contrast as compared with arrangements in which a depixelating screen is located between the optical system and the LCD display. Furthermore, the configuration illustrated in Figure 14 serves to protect the depixelating element and to reduce the overall thickness of the display assembly.

Figure 15 illustrates an alternative arrangement in which the depixelating screen is located between the optical system and the eye of the observer.

In a further variant, (not shown), of the arrangement of Figure 15, the depixelating screen may be disposed between elements in the optical system.

A depixelating or diffusing screen as described above may be made by any of a variety of techniques in any of a variety of materials. Thus, the depixelating or diffusing screen may be of glass or plastics, such as acrylic plastics, polyester, polycarbonate or cellulose acetate and may comprise a homogeneous sheet or may comprise a thin layer or coating of plastics on a substrate of glass or plastics.

Manufacturing techniques which may be used include embossing of the softened plastics by press platen or by embossing roll, injection moulding of the plastics, casting of curable (thermosetting) resins, photolithography, serial "writing" of the formations 14 by laser ablation, or electron beam or ion beam ablation.

CLAIMS

1. A diffuser or depixelating screen comprising a sheet of light-transmitting or reflecting material incorporating an array of features characterised by relatively abrupt surface level or refractive index transitions at their boundaries.

2. A diffuser comprising a sheet of light-transmitting material having on at least one surface thereof a plurality of light-diverting or modifying structures each comprising a flat surface parallel with the plane of major extension of the sheet and a flank or wall extending from said flat surface to a perimeter spaced from the plane of said flat surface.

3. A diffuser according to claim 2 wherein the flank or side walls of the light-diverting structures are perpendicular to said flat surfaces and to the plane of major extension of the sheet material.

4. A diffuser according to claim 2 wherein the flanks or side walls of the light diverting structures are inclined with respect to said flat surfaces and to the plane of major extension of the sheet material.

5. A diffuser according to claim 2 wherein said light-diverting structures comprise circular cylindrical or frusto-conical flanks.

6. A diffuser according to claim 2 wherein said light-diverting structures comprise a plurality of plane faces or facets.

7. A depixelating material, as herein defined, comprising a sheet bearing an array of light-diffracting structures.

8. A depixelating material according to claim 7 wherein said sheet comprises a layer of light-transmitting material and said structures comprise surface relief structures on a surface of said layer.

9. A depixelating material according to claim 7 wherein said sheet comprises a layer of light-transmitting material and said structures comprise regions, in said sheet, of a refractive index different from that of the intervening regions.

10. A depixelating material according to claim 7 wherein said sheet comprises a layer of light-reflective material and said structures comprise surface relief structures on a surface of said layer.

11. A depixelating material according to claim 7 wherein said sheet comprises light transmissive regions and opaque regions cooperating to afford a light-diffracting array.

12. A depixelating material according to claim 8 wherein said surface relief structures each comprise a flat surface (as herein defined) parallel with the plane of major extension.

13. A video or the like display comprising an imaging apparatus which, in operation, provides a regular array of image-forming elements or pixels, with intervening non-image forming elements and further comprising a depixelating material according to any of claims 7 to 11

having a similar regular array of light diffracting features spaced from the image surface of said array of image forming elements or pixels, the dimensions and spacing of said pixels or image forming elements, the dimensions and spacing of the light-diffracting structures and the spacing of the array of light diffracting features from said array of pixels or image forming elements being such that, to an observer of the display, the inter-pixel or picture element spaces are rendered imperceptible by diffracted light emanating from the neighbouring pixels or picture elements.

14. A diffuser or depixelating screen comprising a sheet of light-transmitting or reflecting material having a surface incorporating an array of surface relief structures having relatively abrupt surface level transition at their boundaries and wherein a second light-transmitting material with a refractive index different from that of air and, where said sheet is of light transmitting material, from that of said sheet, is applied over at least portions of said surface of said sheet.

15. A diffuser or depixelating screen according to claim 14 wherein said surface relief structures comprise discrete bodies or islands, integral with said sheet of light-transmitting material and projecting from a base portion of said surface, and wherein said second light-transmitting material is applied over said base portion of said surface.

16. A diffuser or depixelating screen according to claim 15 wherein said second light-transmitting material is applied to a depth less than the height of said surface relief structures so that said surface relief structures project from said second material.

17. A diffuser or depixelating screen according to claim 15 wherein said second light-transmitting material is applied to a depth equal to the height of said surface relief structures so that the latter lie flush with the exposed surface of said second material.

18. A diffuser or depixelating screen according to claim 15 wherein said second light-transmitting material is applied to a depth greater than the height of said structures so that said second material covers said structures in addition to the intervening base surface.

19. A diffuser or depixelating screen according to claim 14 wherein said surface relief structures comprise depressions, grooves or pits in said base portion of said surface and wherein said second light-transmitting material partially or wholly fills said depressions, grooves or pits to a predetermined depth.

20. A diffuser or depixelating screen according to claim 19 wherein said predetermined depth is equal to the depth of said depressions, grooves or pits so that said second material has a surface flush with said base surface.

21. A diffuser or depixelating screen according to claim 19 wherein said predetermined depth is greater than the depth of said depressions, grooves or pits, so that said second material overlies said base surface also.

22. A diffuser or depixelating screen according to any of claims 14 to 26 wherein said second material is a solid.

23. A diffuser or depixelating screen according to any of claims 14 to 26 wherein said second material is a liquid.

24. A diffuser or depixelating screen according to claim 22 wherein said second material is a plastics material.

25. A diffusing or depixelating screen according to any of claims 14 to 24 wherein said second material itself has light-modifying surface structures and/or refractive index variations.

26. A diffusing or depixelating screen according to claim 25 wherein at least some such light-modifying surface structures or refractive index variations are not in register with or in simple correspondence with said structures of said base sheet.

27. A diffusing or depixelating screen according to claim 25 or claim 26 wherein said second material has an exposed surface configured to provide an array of lenses or analogous light-refracting structures.

28. A diffusing or depixelating screen according to claim 25 or claim 26 wherein said second material has refractive index variations therein such as to afford array of graded refractive index lenses.

29. A diffuser or depixelating material substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

30. A video or the like display substantially as hereinbefore described.

31. A method of forming a diffusing or depixelating material substantially as hereinbefore described.

32. Any novel feature or combination of features described herein.

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The Patent Office

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Claims searched:	1-6,14-29,31	**Date of search:**	3 September 1997

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G2X(X42B),G2F(FSX)

Int Cl (Ed.6): G03B,G02B,G02F

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2118210A	(Marconi)(Figs 1-2,page 3)	1,14 at least
X	GB 2048514A	(MMM)(Figs 1-2)(	"
X	GB 1419945	(Freen)(Figs 3,5-6)	1,2 at least
X	GB 782033	(Jacbson)(Figs 1,5)	1 at least
X	GB 481435	(Tansini)(Figs)	1-2 at least
X	GB 477825	(Lennard)(Figs 3-7)	"
X	EP 0163766A	(Mitsubishi)(Figs 10-13,page 10)	1-2,14 at least
X	WO 87/01470A	(Scan)(Figs 2-10)	1-2 at least
X	WO 83/01310A	(MMM)(Figs 1,5)	1 at least
X	US 4329019	(Okoshi)(Figs 5-9,Cols 5-6)	1-2 at least
X	US 3966301	(Qantix)(Figs 4-6,8-9)	1 at least
~~X~~	~~US 3966301~~		

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.